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(54) **Look-up table based gamma and inverse gamma correction for high-resolution frame buffers**

Gammakorrektur und invertierte Gammakorrektur mit Nachschlagtabellen für hochauflösende Rasterpuffer

Correction et correction inverse de gamma avec des tables de consultation pour des tampons de trame à haute résolution

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**1984**

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## Description

This invention relates generally to image display apparatus and method and, in particular, to apparatus and method for applying a non-linear transform to a displayed image.

The light output of a phosphor from a cathode-ray tube (CRT), also referred to herein as a monitor, exhibits a power-law relationship to a video signal voltage applied to the CRT's cathode. To compensate for this non-linear behavior, the video signal is predistorted with a power-law function which is the inverse of that performed by the CRT. The resultant signal modulates the CRT cathode such that a linear transition of the light levels in the scene or image produce a linear transition in the light output of the CRT phosphors.

CRT light output (luminance) is defined by the power law function  $L = E^Y$ , where  $E$  is video signal voltage and  $y$  is the power function exponent, referred to as gamma. Gamma is typically in the range of 2 to 3 for most CRT displays. To produce linear transitions in CRT light output,  $E$  is transformed to  $E'$  by the relation  $E' = E^{1/Y}$ . This mathematical process is known as an inverse gamma function or, more commonly, as gamma correction. Image data which has been gamma corrected can, in turn, be linearized by applying the gamma function  $E = E'^Y$  to the data. This process is known as inverse gamma correction.

Figs. 1a-1d illustrate the function of gamma correction during image reproduction. In these figures a human observer is replaced with a photometer so as to quantify the light output of the monitor. In computer graphics systems, wherein an image is synthesized by the computer, the computer/renderer/database behavior, which generates the image, is functionally identical to the camera in the image reproducer chain. Inverse gamma correction therefore applies the monitor's function to a gamma-corrected input signal, yielding a linearized output.

In digital video systems, gamma correction may be performed on an image using two distinct techniques. A first technique performs gamma correction on each picture element (pixel) as it is generated by the imaging system. Subsequently, these gamma corrected pixels are stored in an image memory, referred to as a frame buffer. Gamma corrected pixels are then read from the frame buffer and presented to a digital-to-analog converter (DAC) for conversion to an analog signal to drive the CRT. However, in that gamma correction is a nonlinear operation, two undesirable effects result.

First, any additional operations performed on these pixels, for example linear mixing of two images, must consider the mathematical impact of the gamma corrected values upon the resultant value, since

$$A + (1 - \alpha) B \neq [\alpha A' + (1 - \alpha) B']^Y$$

(where  $A$  and  $B$  are the linear pixel values,  $A'$  and  $B'$  are the gamma corrected pixel values, and  $\alpha$  is the mixing ratio). Hence, a mixing operation must first inverse gamma correct the two pixels before mixing, and then gamma correct the result before storage. This is obviously a time consuming process and may be impractical for large numbers of pixels.

Second, as will be illustrated below, a gamma corrected integer pixel requires more bits than a linear integer pixel in order to uniquely define an identical set of intensity values. This in turn requires a larger frame buffer and long-word arithmetic capability.

A second technique stores and performs mathematical operations upon linear pixel values, and then performs gamma correction just prior to converting the pixels to an analog voltage by means of a look-up table (LUT) operation. The linear pixel values read from the frame buffer are used as an index to a memory (LUT) whose contents have been precalculated to satisfy the above mentioned gamma correction equation. It is the LUT's contents which are then applied to the DAC.

Performing gamma correction on integers with  $y > 1$  requires that the output set of integers contain more numbers than the input set, in order to maintain unique numbers. This can be observed when performing gamma correction on 8-bit integers (a common pixel size for digital video samples) for  $y = 2.0$ . The transformed 8-bit output integers exhibit 64 duplicates, for a loss of 25% of the input set values. Referring to Table 1 in Appendix A it can be seen that increasing  $y$  to only 2.2 yields 72 duplicates for a loss of over 28%. Clearly, losses of these magnitudes are unacceptable in a high quality digital video system.

The use of a look-up memory or look-up table (LUT) to provide gamma correction has been previously employed as indicated by the following U.S. Patents.

In U.S. Patent No. 4,805,013, issued February 14, 1989, entitled "Image Data Conversion System" to Dei et al. there is disclosed the use of a RAM for storing a gamma conversion table. A CPU is enabled to load gamma conversion data that corresponds to a gamma conversion curve calculated by the CPU into the RAM.

In U.S. Patent No. 4,394,688, issued July 19, 1983, entitled "Video System Having an Adjustable Digital Gamma Correction for Contrast Enhancement" to Iida et al. there is disclosed a video system that includes a RAM in which video data is altered in accordance with the contents of a table look-up that is temporarily written therein. A ROM device stores a plurality of different table look-ups, each containing data representing a different gamma correction. A CPU

obtains a table look-up from the ROM and writes same into the RAM. This technique enables the selection of only a single table look-up, and therefore a single gamma correction per image.

In U.S. Patent No. 4,688,095, issued August 18, 1987, entitled "Programmable Image-Transformation System" to Beg et al. there is described an image processing system having a multiplexor that supplies address signals to a look-up table whose resulting output is applied as data to a frame buffer. By changing selection signals applied to the multiplexor, it is said to be possible to use this system alternately for transformations dependent only on newly generated data, transformations dependent only on stored data, and transformations dependent on both. The look-up table may store different correction functions for each of 16 different combinations of camera and display device. The look-up table address is formed from a combination of possible sources including an output of an eight bit A/D and the output of a four bit register. In operation, a computer loads the look-up table and, if necessary, loads a value into the register to designate a portion of the look-up table to be used. The disclosure of Beg et al. permits gamma correction to be performed only on incoming video data from the A/D and, if the A/D data is linearized, it is not re-gamma corrected before DAC processing and display. As a consequence, if non-linearized data were to be placed in the frame buffer of Beg, any operation performed upon this data must compensate for the non-linear data. Furthermore, Beg et al. sample a gamma corrected signal with eight-bit accuracy and effectively do not use at least 2-bits/pixel in the frame buffer when linearizing a gamma corrected pixel.

In U.S. Patent No. 4,568,978, issued February 4, 1986, entitled "Method of a Circuit Arrangement for Producing a Gamma Corrected Video Signal" to Cosh there is disclosed a method for correcting a video signal by a gamma correction factor. A gamma correction circuit forms a logarithm of an input signal and a logarithm of a correction factor. The two logarithmic signals are summed and an anti-logarithm of the exponential of the summed signal is taken. PROMs are employed for storing conversions. Cosh notes that for each input code to translate to a unique output code the output code must have four times the resolution of the input code. For example, if the input is defined by 10 bits the output should have 12 bits.

It is thus one object of the invention to provide an improved image display system and method. The object of the invention is solved by the features laid down in the independent claims.

The invention provides for a method for determining an optimum number of bits required for a gamma correction look-up table output so as to achieve unique values for a specified number of input bits and for a selected range of gamma values.

In particular, the invention further provides an image generation system that includes an image buffer that receives and stores linear, gamma corrected digital data and that outputs the linear data to an inverse gamma corrector.

Further, the invention particularly provides a pixel-by-pixel selection of a function to be applied to each pixel so as to enable a gamma windowing function to be implemented, wherein a foreground gamma correction is applied to a window in a display, the foreground gamma correction being different than a background gamma correction and especially a dynamically programmable LUT memory in combination with a frame buffer having one or more (N-bit + W-bit) planes, where N-bits represent linear information, such as color, and wherein W-bits represent a display window identifier.

The foregoing and other problems are overcome and the object of the invention is realized by a digital video system architecture and method as defined in claims 1, 10 and 15 which provides a power-full and flexible means of performing non-linear transformations upon digital image data. The invention may employ read/write look-up table memories to perform arbitrary non-linear operations upon image data, either over an entire image or within user-defined windows into the image. The teaching of the invention is particularly useful for performing gamma and inverse gamma correction to image data, but may also be applied to provide enhancement and restoration capabilities for image analysis. The teaching of the invention may further be applied so as to modify an image to obtain a desired aesthetic effect.

The invention provides method and apparatus for performing gamma correction upon digital video values on a per pixel basis with minimal or no loss of information during the transform process. The invention pertains to both the transformation of linear intensity values to gamma corrected values and to the transformation of gamma corrected intensity values to linear values.

In that gamma correction and inverse gamma correction are specific cases of a more general class of non-linear transforms of image intensity, the teaching of the invention may employed so as to alter the transfer characteristic of the video display generally. Thus, analytic or aesthetic enhancements of the image may be accomplished.

In accordance with an exemplary embodiment of the invention, an image processing system includes an input to a source of image pixel data wherein each pixel has an M-bit value within a non-linear range of values. A first LUT is coupled to an output of the source and converts each M-bit pixel value to an N-bit value within a linear range of values. An image memory, or frame buffer, has an input coupled to an output of the first LUT and stores the linear N-bit pixel values. The system further includes a second LUT coupled to an output of the frame buffer for converting N-bit pixel values output by the frame buffer to P-bit pixel values within a non-linear range of values. The converted values are subsequently applied to a display.

In an exemplary embodiment, the first LUT stores gamma corrected pixel values and the second LUT stores inverse

gamma corrected pixel values.

Preferably the second LUT stores a plurality of sets of inverse gamma corrected pixel values. Also, the frame buffer further stores, for each of the N-bit pixel values, a value that specifies a particular one of the plurality of sets of inverse gamma corrected pixel values for use in converting an associated one of said N-bit pixel values.

The above set forth and other features of the invention are made more apparent in the ensuing detailed description of the invention when read in conjunction with the attached drawing, wherein:

- Figs. 1a-1d illustrate the process of gamma correction and inverse gamma correction, wherein Fig. 1a shows a linear output of a camera, Fig. 1b illustrates a gamma correction that is applied to the camera output, Fig. 1c shows the inverse gamma correction applied at a display (monitor), and Fig. 1d shows the output of a photometer that is a linear function due to the gamma correction applied to the camera output;
- Fig. 2 illustrates a simplified look-up table based inverse gamma correction/gamma correction block diagram for a digital video system;
- Fig. 3 illustrates a window-based graphic system that employs a LUT-based inverse gamma correction technique to mix images from cameras with different gamma corrections;
- Fig. 4 illustrates the simultaneous use of different gamma functions to obtain contrast expansion;
- Fig. 5 shows a frame buffer memory constructed so as to have a plurality of input gamma correctors and a plurality of output gamma correctors;
- Fig. 6 illustrates in greater detail the input inverse gamma correctors shown in Fig. 5; and
- Fig. 7 illustrates in greater detail the output gamma correctors shown in Fig. 5.

Fig. 2 illustrates a simplified block diagram of a look-up table based inverse gamma correction/gamma correction technique for use in a digital video system. Signal inputs from the camera 10 and outputs to monitor 24 are presumed to be analog. The inputs and outputs of the constituent blocks are indicated to be analog or digital and linear or non-linear by the attendant pictographs. The gamma correction block 12 following the camera 10 is an analog function typically built into the camera 10. Following the gamma correction block 12, that is, the output of the camera 10, is an analog-to-digital converter (ADC) 14 that provides M digital outputs to the address inputs of a first LUT, specifically a inverse gamma correction (IGC) LUT 16. The output of LUT 16 is N-bits that are applied to an input of a frame buffer (FB) 18. The output of FB 18 is N-bits that are applied to the address inputs of a second LUT, specifically a gamma correction (GC) LUT 20. The output of GC LUT 20 is P-bits ( $P \geq N$ ) of digital gamma corrected video data that is applied to an input of a DAC 22. The output of DAC 22, for a color system, is three analog signals. These three analog signals are a red (R) analog signal, a blue (B) analog signal, and a green (G) analog signal. Analog signals are applied to monitor 24, resulting in the display of a gamma corrected image.

For a high quality camera 10 the operation of the gamma correction block 12 may be disabled. Thus, the outputs to the ADC 14 are linear and the gamma correction action of the IGC LUT 16 is suppressed. Also, for image data generated by a source other than a camera, such as by a digital computer, linear video data may be applied directly to the FB 18. In any case, the approach of the system is to preserve linear color representation in the FB 18.

Fig. 3 illustrates a window based graphics system that employs the LUT-based inverse gamma correction technique if Fig. 2 to mix images from sources, such as cameras, having different gamma corrections. By applying the appropriate inverse gamma correction to each camera source, in real time, all images are linearized in the FB 18 and are therefore displayed on a common monitor 14 without losing intensity values in any of the windows.

While the LUT gamma correction technique described thus far provides a fast and inexpensive means of performing non-linear transforms upon pixel values, two enhancements may be made. Specifically, in that the pixel values which serve as the addresses into the LUTs and the data read from the LUTs are integers, loss of information, and therefore errors, may be produced by gamma correction if insufficient attention is given to the range of values which are required to uniquely represent all of the input set of values in the output set of values.

Secondly, since the LUT based gamma correction technique of the invention does not affect the pixel values stored in the FB 18, a separate means is provided to provide a pixel-accurate gamma window function. In this case a user, on a pixel-by-pixel basis, selects which one of a plurality of precalculated gamma functions are to be applied to specific areas (windows) on the display. By example, Fig. 4 shows the simultaneous use of different gamma functions to obtain contrast expansion, and illustrates a technique whereby a user expands low contrast areas, or alternately compresses high contrast areas, within a window in order to observe image detail which may otherwise be unintelligible.

In accordance with an aspect of the exemplary embodiment of invention, a method for determining a minimum number of bits required for the LUT output, to achieve unique values for a specified number of input bits and for a selected range of gamma values, is now presented. More specifically, this method determines a scaling coefficient S which, when used with the identity relation  $E = [S(e)^{1/y}/S]^y$ , provides recovery of all integer values of E. Since this relation is the mathematical equivalent of the inverse gamma function (gamma correction) performed by the digital

imaging system and the gamma function performed by the monitor 24, the coefficient S determines the number of bits of any intermediate integers used in the transform and inverse transform process.

For a case where the camera gamma is not equal to the monitor gamma,  $P \neq M$ , and the scale factor S is found to satisfy the following relations:

$$O = \text{INT}[(P-1)(I/N-1)^{1/y} + 0.5]$$

and

$$I = \text{INT}[(N-1)(O/P-1)^y + 0.5],$$

where  $N \equiv$  number of linear input levels,  $P =$  number of gamma corrected output levels,  $(I/N-1)$  and  $(O/P-1)$  are normalized input and output values, respectively,  $S = P-1$ , and INT is a truncating integer function. The above mentioned identity equation is obtained by substituting the equation for O into that for I. Therefore, for  $N = \log_{2n}$  number of input bits,  $P = (N + 1)$  for  $y > 1$ . The value of P is increased until the identity is satisfied, i.e. no duplicates are generated. The tables shown in Appendices A and B, respectively, illustrate the effect of increasing P from 8 to 10 bits for  $y = 2.2$ . Appendix A shows the large number of duplicate values produced for  $P = 8$ -bits, while Appendix B shows that with  $P = 10$ -bits that no duplicate values are generated. As a result, there is no loss of intensity information over the range of input bits. It can be empirically determined that for  $N = 8$ ,  $P = 10$  satisfies the identity relation for  $1 \leq \gamma \leq 4.2$ .

Performing inverse gamma correction, i.e. linearizing intensity which was previously gamma corrected, requires a smaller output data set than the input data set. By example, this may be required after sampling a video camera which has a gamma corrected analog output, as is frequently the case. The IGC LUT memory 16 operating at a sample clock frequency instantaneously performs the transform. From the above example, a 10-bit (M) camera sample is used as the index to the IGC LUT 16 which generates an 8-bit (N) linear output value for  $1 \leq \gamma \leq 4.2$ . This is an efficient process since the resultant 8-bit transformed sample may then be directly mixed with other 8-bit linear values so as to form composite video images in real time.

The block diagram of Fig. 5 shows in greater detail data paths using the integers I and O. When digitizing a gamma corrected analog input, as from a camera, care should be taken when mapping the larger data set O to the smaller data set I. A median value method may be employed to select which intermediate numbers in the O set are assigned to those in the I set. The use of a median value may be illustrated by an example taken from Table 2 of Appendix B. The analog input is digitized with 10-bit accuracy. Any number from 0 to 1023 may be obtained at the output of the ADC 14, such as the values 264, 265, 266, etc. In order to determine the corresponding number at the output (O) of the LUT 16 for such intermediate inputs (I) a median value is determined. For example, the median value of 264 and 274 is 268, and the median value of 255 and 264 is 260. Thus, to all ADC 14 generated inputs between, by example, 260 and 268 only one output number (13) is assigned.

In Fig. 5 the FB 18 has a plurality of  $N+W$ -bit planes, where N-bits represents linear color information and where W-bits represents a window identification number (WID). All bit planes of FB 18 are accessible by a host (not shown). The gamma compensated input source is sampled with the ADC 14, which has M bits per pixel output. The input data is converted to linear data with Inverse Gamma Correction LUT 16 which outputs N bits per pixel. On the video output, for each pixel there are  $N + W$  bits. The N bit linear color data is gamma corrected with one of  $2^W$  gamma correction tables stored within the Gamma Correction Block LUT 20, based on WID, which outputs P bits per pixel. These P bits are in turn loaded into the DAC 22 to be displayed on the monitor 24. This technique supports simultaneous multiple gamma corrections based on the WID associated with each pixel stored in the FB 16. Thus, there may be as many as  $2^W$  different gamma corrected windows present within the system video output, as shown in Fig. 3 for the case of three gamma corrected windows ( $W_1, W_2, W_3$ ).

#### Input Device

The following is the description of the input inverse gamma correction logic as shown in Fig. 6. The gamma corrected analog input signal, such as a signal from the video camera 10, is sampled and converted to M-bit digital data by the ADC 14. The linearization of the sampled gamma corrected data is performed by the IGC LUTs 16 which convert M-bits into N-bits. The value of M is determined, as described above, by the maximum value of input device gamma  $y$ . As indicated above,  $M = 10$  for  $N = 8$  for reasonable values of  $y$ .

It may be desirable to write the sampled data into the FB 16 in parallel. For example, if Video RAM (VRAM) chips utilized to implement the FB 16 have a random port bandwidth of 16.6 Mhz (60 nS cycle time), then in order to store a HDTV camera signal sampled at 74.25 Mhz, the memory must be interleaved at least 5 ( $j = 5$ ) ways to provide

sufficient bandwidth to store the sampled data. The transformation may be accomplished immediately after the ADC 14, before parallelization, by employing a fast LUT 16 which matches the period of a sample clock (SAMPLE\_CLOCK). Alternately, the transformation may be done after parallelization, by using a slower LUT 16 which matches the FB 18 cycle period. The second method is illustrated in Fig. 6 and is preferred over the first since slower LUT 16 memory is more readily available and operates independently of the high speed sample clock.

The circuitry of Fig. 6 functions in the following manner. The analog input signal is sampled and clocked at the ADC 14 every sample clock period (SAMPLE\_CLOCK). The output of the ADC 14 is loaded into registers REG\_1 through REG\_J in a round robin fashion via signals LD\_1 through LD\_J, respectively. Thus, the first sampled data is loaded into REG\_1 with the LD\_1-strobe, the second sampled data is loaded into REG\_2 with LD\_2-strobe, and so on, until the last round robin LD\_J strobe is generated. On the following SAMPLE\_CLOCK period, a new robin cycle is initiated by again strobing LD\_1. Simultaneously, the data already stored within REG\_1 through REG\_J is parallel loaded into REG\_J + 1 through REG\_2j. Thus, the LD\_1 strobe controls the loading of REG\_1 and all of the registers REG\_j+1 through REG\_2j.

The data stored in REG\_j+1 through REG\_2j are used as address inputs to a set of IGC LUTs 16, which in turn provide N bit linear data to the FB 18. The contents of LUTs 16 are updated from the local host via host computer address bus (WS\_ADDR); host computer data bus (WS\_DATA); and control signals IGC LUT Enable (WS\_EN\_IGC-) and IGC LUT write strobe (WS\_WRT\_IGC-). Normally, both WS\_EN\_IGC- and WS\_WRT\_IGC- are deasserted. When deasserted, WS\_WRT\_IGC- selects multiplexors (MUX\_1 through MUX\_j) outputs to be sourced from registers REG\_j+1 through REG\_2j, thereby providing the sampled data from the ADC 14. This signal also forces local host data buffers (BUF\_1 through BUF\_j) into a high impedance mode, and enables the output of LUTs 16, thus enabling the linearized color data to be available to FB 18. During an IGC LUT 16 update cycle by the local host, the local host first asserts the WS\_EN\_IGC- signal, which causes MUX\_1 through MUX\_j to select the WS\_ADDR as address inputs to the LUTs 16, and disables the LUTs 16 outputs. The BUF outputs are enabled such that WS\_DATA is used as the input to the LUTs 16 data ports. Subsequently, the local host strobes WS\_WRT\_IGC- which loads the WS\_DATA into the LUTs 16 at the address specified by WS\_ADDR.

#### Video Output Device

The following is the description of the video output device shown in Fig. 7. It may be required that the serial output port of the FB 18 be parallelized to achieve a desired video bandwidth. For example, a 60 Hz 1280 x 1024 resolution display requires a bandwidth of 110MHz. Since a typical VRAM has serial output bandwidth of less than 40 MHz, the FB 18 serial output must be interleaved at least four ways. The interleaved serial outputs of the FB 18 are then loaded into the serializer 26 which is capable of being shifted at the video clock rate.

There are two methods to implement gamma correction using the GC LUT memories 20. The transformation may be done after serialization, just before the DAC 22, by using high speed LUTs 20 that match the video clock period. Alternately, gamma correction can be accomplished before serialization by employing slower LUT memories 20 that match the VRAM serial output cycle period. The second method is preferred over the first method in that slower LUT memory is more readily available and operates independently of the video clock period. Fig. 7 illustrates this second, preferred approach.

N-bits of linear color value is gamma corrected by the GC LUTs 20. The result is P-bits of gamma corrected data which is input to the DAC 22, via serializer 26. DAC 22 thus has a P-bit wide input.

As was discussed previously, the actual value of P is a function of the required gamma value for video output correction. For the case where the monitor gamma and camera gamma are relatively close, then P may equal M. For some cases the output correction may require more bits or the same number of bits as the input correction. For example, if the gamma of the monitor is equal to 1, then P may equal N. As was previously stated, a general rule is that  $P \geq N$ .

For certain special effects, different gamma corrections may be applied based on the value of WID, as illustrated in Figs. 3 and 4. This is accomplished by FB 18 containing the plurality of N+W-bit planes, where N-bits represent linear color data and W-bits the WID. Therefore, each pixel is represented, in each FB 18 memory plane, by N+W-bits of data. N-bit video data from the FB 18 is concatenated with the W-bit WID. As an example, if WID is represented by three bits then  $2^3$ , or eight, different gamma corrections can be simultaneously in effect for a given display screen frame. This corresponds to eight distinct windows.

It is noted that different gamma corrected pixel regions can be overlapped because, after gamma correction, all images are linearized. For example, in Fig. 3 it is assumed that window 3 was sampled last and also incidentally overlaps window 2. The images are not overlapped, but a portion of the overlap window is rewritten during sampling or rewritten by the local host. If mixing of two images is required the mixing does not occur in real time. By example, sampling is disabled in window 2 and a portion of the window 2 which may be overlapped is stored by the local host. Sampling is again enabled and window 3 is sampled. Sampling is then disabled and the local host then mixes the image pixels from each of the overlapped regions.

During normal operation, both a local host enable gamma correction signal (WS\_EN\_GC-) and a local host write gamma correction( WS\_WRT\_GC-) signal are deasserted. As such, WS\_EN\_GC- forces multiplexors (MUX\_1 through MUX\_k) to select the concatenated VIDEO\_DATA and WID; disables local host data buffers (BUF\_1 through BUF\_k); and enables the LUT 20 output. Therefore, the output of the LUTs 20 provide the gamma corrected P-bit value, based on address supplied by the N-bit linear color data, from a selected one of the  $2^w$  gamma correction tables, based on WID. That is, by changing the value of WID different regions of the GC LUT 20 are addressed.

For the example shown in Fig. 3, the pixels within window 1 are gamma corrected from a first correction table stored within GC LUT 20, the pixels within window 2 are gamma corrected from a second correction table stored within GC LUT 20, etc. The simultaneous use, within a display screen, of different correction tables enables image data from various sources to be displayed at, for example, one brightness level. Also, different regions (windows) of a displayed image can be given different brightnesses or contrasts as desired for a particular application.

Data is shifted out of the serializer 26 at every video clock (VID\_CLK). On every k-th VID\_CLK, a signal LD\_VID\_DATA- is generated, which parallel loads parallel data, the output of LUTs 20, into the serializer 26 shift registers.

During a GC LUT 20 update cycle by the local host, the local host first asserts the WS\_EN\_GC- signal, which causes MUX\_1 through MUX\_K to select the WS\_ADDR as the output of the MUXs. The assertion of the WS\_EN\_GC- signal also disables the LUT 20 outputs and enables the BUF outputs, such that WS\_DATA is used as the input to the LUTs 20 data port. Subsequently, the local host strobes WS\_WRT\_GC-, which loads the WS\_DATA into the LUTs 20 using the address provided by WS\_ADDR.

It should be noted that for a R, G, B frame buffer 18, there are three sets of IGC LUTs 16 and GC LUTs 20, one for each of the R, G, B, data paths. However, there is only one WID path, since all R, G, B data bits are applied to the same window. Thus, a minimum number of bit planes is  $3N+W$  for the RGB system. This provides independent gamma correction for each color component for both the input and the output of the FB 18.

The foregoing has disclosed methods and apparatus for performing non-linear pixel based intensity transforms, such as gamma and inverse gamma correction, upon digital video data. The use and design of LUT memories to perform these operations has been described. Also, use of a secondary pixel plane to select from multiple gamma functions in the LUT provides a windowing capability to specifically support multiple display gammas, in addition to generally performing non-linear image processing within a window. Furthermore, the significance of input-to-output number capacity has been addressed so as to minimize losses for gamma transforms in both directions. Also, a method for determining adequate integer number ranges for both transforms has been disclosed.

## APPENDIX A

TABLE 1

$$n = 256$$

$$m = 256$$

$$y = 2.2$$

$$S = (m - 1) = 255$$

$$O = \text{INT}[(m - 1) \left( \frac{I}{n - 1} \right)^{\frac{1}{y}} + 0.5]$$

$$I = \text{INT}[(n - 1) \left( \frac{O}{m - 1} \right)^y + 0.5]$$

	I		O		I
	---		---		---
	0	0.0000	0	0.0000	0
20	1	20.5427	21	1.0496	1
	2	28.1508	28	1.9765	2
	3	33.8479	34	3.0297	3
	4	38.5764	39	4.0973	4
	5	42.6945	43	5.0790	5
25	6	46.3835	46	5.8914	6
	7	49.7501	50	7.0776	7
	8	52.8632	53	8.0456	8
	9	55.7705	56	9.0817	9
	10	58.5065	59	10.1865	10
	11	61.0968	61	10.9617	11
30	12	63.5617	64	12.1828	12
	13	65.9168	66	13.0361	13
	14	68.1751	68	13.9210	14
	15	70.3469	70	14.8377	15
	16	72.4412	72	15.7864	16
35	17	74.4652	74	16.7672	17
	18	76.4252	76	17.7804	18
	19	78.3267	78	18.8261	19
	20	80.1744	80	19.9044	20
	21	81.9723	82	21.0156	21
40	22	83.7241	84	22.1598	22
	23	85.4330	85	22.7443	23
	24	87.1018	87	23.9383	24
	25	88.7331	89	25.1657	25
	26	90.3292	90	25.7920	26
	27	91.8921	92	27.0698	27
45	28	93.4238	93	27.7213	28
	29	94.9259	95	29.0498	29
	30	96.4000	96	29.7268	30
	31	97.8476	98	31.1064	31
	32	99.2699	99	31.8089	32
50	33	100.6681	101	33.2398	33
	34	102.0434	102	33.9682	34
	35	103.3969	103	34.7051	35
	36	104.7294	105	36.2050	36
	37	106.0418	106	36.9679	37
55	38	107.3351	107	37.7395	38
	39	108.6099	109	39.3088	39



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	40	109.8670	110	40.1066	40	
	41	111.1071	111	40.9131	41	
	42	112.3308	112	41.7284	42	
5	43	113.5387	114	43.3853	43	
	44	114.7314	115	44.2270	44	
	45	115.9094	116	45.0775	45	
	46	117.0731	117	45.9368	46	
	47	118.2232	118	46.8050	47	
10	48	119.3600	119	47.6821	48	
	49	120.4840	120	48.5680	49	
	50	121.5955	122	50.3667	50	
	51	122.6949	123	51.2794	51	
	52	123.7827	124	52.2011	52	
15	53	124.8591	125	53.1317	53	
	54	125.9244	126	54.0713	54	
	55	126.9791	127	55.0199	55	
	56	128.0234	128	55.9775	56	
	57	129.0575	129	56.9442	57	
20	58	130.0818	130	57.9198	58	
	59	131.0965	131	58.9045	59	
	60	132.1018	132	59.8983	60	
	61	133.0981	133	60.9011	61	
	62	134.0855	134	61.9131	62	
25	63	135.0642	135	62.9341	63	
	64	136.0345	136	63.9643	64	
	65	136.9966	137	65.0035	65	
	66	137.9506	138	66.0520	66	
	67	138.8968	139	67.1096	67	
30	68	139.8353	140	68.1763	68	
	69	140.7663	141	69.2522	69	
	70	141.6900	142	70.3374	70	
	71	142.6065	143	71.4317	71	
	72	143.5160	144	72.5353	73	
35	73	144.4186	144	72.5353	73	**
	74	145.3145	145	73.6481	74	
	75	146.2039	146	74.7701	75	
	76	147.0868	147	75.9014	76	
	77	147.9633	148	77.0420	77	
40	78	148.8337	149	78.1919	78	
	79	149.6980	150	79.3510	79	
	80	150.5564	151	80.5195	81	
	81	151.4089	151	80.5195	81	**
	82	152.2557	152	81.6973	82	
45	83	153.0969	153	82.8844	83	
	84	153.9326	154	84.0809	84	
	85	154.7629	155	85.2867	85	
	86	155.5879	156	86.5019	87	
	87	156.4076	156	86.5019	87	**
50	88	157.2223	157	87.7265	88	
	89	158.0319	158	88.9605	89	
	90	158.8365	159	90.2039	90	
	91	159.6363	160	91.4567	91	
	92	160.4313	160	91.4567	91	**
55	93	161.2216	161	92.7190	93	
	94	162.0073	162	93.9907	94	

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	95	162.7884	163	95.2718	95	
	96	163.5651	164	96.5624	97	
5	97	164.3374	164	96.5624	97	**
	98	165.1053	165	97.8625	98	
	99	165.8690	166	99.1721	99	
	100	166.6285	167	100.4912	100	
	101	167.3838	167	100.4912	100	**
10	102	168.1351	168	101.8198	102	
	103	168.8824	169	103.1579	103	
	104	169.6257	170	104.5056	105	
	105	170.3651	170	104.5056	105	**
	106	171.1007	171	105.8628	106	
15	107	171.8326	172	107.2295	107	
	108	172.5607	173	108.6058	109	
	109	173.2851	173	108.6058	109	**
	110	174.0059	174	109.9918	110	
	111	174.7232	175	111.3873	111	
20	112	175.4369	175	111.3873	111	**
	113	176.1472	176	112.7923	113	
	114	176.8541	177	114.2071	114	
	115	177.5575	178	115.6314	116	
	116	178.2577	178	115.6314	116	**
25	117	178.9546	179	117.0654	117	
	118	179.6482	180	118.5090	119	
	119	180.3386	180	118.5090	119	**
	120	181.0259	181	119.9623	120	
	121	181.7100	182	121.4252	121	
30	122	182.3911	182	121.4252	121	**
	123	183.0691	183	122.8978	123	
	124	183.7442	184	124.3801	124	
	125	184.4163	184	124.3801	124	**
	126	185.0854	185	125.8721	126	
35	127	185.7517	186	127.3738	127	
	128	186.4151	186	127.3738	127	**
	129	187.0756	187	128.8853	129	
	130	187.7334	188	130.4064	130	
	131	188.3885	188	130.4064	130	**
40	132	189.0408	189	131.9373	132	
	133	189.6904	190	133.4780	133	
	134	190.3374	190	133.4780	133	**
	135	190.9817	191	135.0284	135	
	136	191.6235	192	136.5886	137	
45	137	192.2626	192	136.5886	137	**
	138	192.8993	193	138.1586	138	
	139	193.5334	194	139.7383	140	
	140	194.1650	194	139.7383	140	**
	141	194.7942	195	141.3279	141	
50	142	195.4210	195	141.3279	141	**
	143	196.0453	196	142.9273	143	
	144	196.6673	197	144.5365	145	
	145	197.2869	197	144.5365	145	**
	146	197.9042	198	146.1555	146	
55	147	198.5192	199	147.7844	148	
	148	199.1319	199	147.7844	148	**
	149	199.7424	200	149.4231	149	

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	150	200.3506	200	149.4231	149	**
	151	200.9566	201	151.0717	151	
	152	201.5605	202	152.7302	153	
5	153	202.1621	202	152.7302	153	**
	154	202.7617	203	154.3985	154	
	155	203.3591	203	154.3985	154	**
	156	203.9544	204	156.0767	156	
	157	204.5476	205	157.7649	158	
	158	205.1388	205	157.7649	158	**
10	159	205.7280	206	159.4629	159	
	160	206.3151	206	159.4629	159	**
	161	206.9002	207	161.1709	161	
	162	207.4834	207	161.1709	161	**
	163	208.0646	208	162.8888	163	
15	164	208.6438	209	164.6166	165	
	165	209.2211	209	164.6166	165	**
	166	209.7965	210	166.3544	166	
	167	210.3701	210	166.3544	166	**
	168	210.9417	211	168.1021	168	
20	169	211.5115	212	169.8598	170	
	170	212.0795	212	169.8598	170	**
	171	212.6457	213	171.6275	172	
	172	213.2100	213	171.6275	172	**
	173	213.7726	214	173.4052	173	
25	174	214.3334	214	173.4052	173	**
	175	214.8924	215	175.1929	175	
	176	215.4497	215	175.1929	175	**
	177	216.0053	216	176.9905	177	
	178	216.5591	217	178.7982	179	
30	179	217.1113	217	178.7982	179	**
	180	217.6618	218	180.6159	181	
	181	218.2106	218	180.6159	181	**
	182	218.7578	219	182.4437	182	
	183	219.3033	219	182.4437	182	**
35	184	219.8472	220	184.2815	184	
	185	220.3895	220	184.2815	184	**
	186	220.9302	221	186.1293	186	
	187	221.4693	221	186.1293	186	**
	188	222.0069	222	187.9872	188	
40	189	222.5429	223	189.8552	190	
	190	223.0773	223	189.8552	190	**
	191	223.6102	224	191.7332	192	
	192	224.1416	224	191.7332	192	**
	193	224.6715	225	193.6214	194	
45	194	225.1999	225	193.6214	194	**
	195	225.7268	226	195.5196	196	
	196	226.2522	226	195.5196	196	**
	197	226.7762	227	197.4280	197	
	198	227.2987	227	197.4280	197	**
50	199	227.8198	228	199.3464	199	
	200	228.3395	228	199.3464	199	**
	201	228.8577	229	201.2750	201	
	202	229.3746	229	201.2750	201	**
	203	229.8900	230	203.2137	203	
55	204	230.4041	230	203.2137	203	**

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	205	230.9168	231	205.1626	205	
	206	231.4281	231	205.1626	205	**
	207	231.9381	232	207.1216	207	
5	208	232.4467	232	207.1216	207	**
	209	232.9540	233	209.0907	209	
	210	233.4600	233	209.0907	209	**
	211	233.9647	234	211.0701	211	
	212	234.4681	234	211.0701	211	**
10	213	234.9701	235	213.0596	213	
	214	235.4709	235	213.0596	213	**
	215	235.9704	236	215.0593	215	
	216	236.4687	236	215.0593	215	**
	217	236.9657	237	217.0692	217	
15	218	237.4614	237	217.0692	217	**
	219	237.9559	238	219.0893	219	
	220	238.4492	238	219.0893	219	**
	221	238.9413	239	221.1196	221	
	222	239.4321	239	221.1196	221	**
20	223	239.9217	240	223.1601	223	
	224	240.4102	240	223.1601	223	**
	225	240.8974	241	225.2108	225	
	226	241.3835	241	225.2108	225	**
	227	241.8684	242	227.2718	227	
25	228	242.3521	242	227.2718	227	**
	229	242.8347	243	229.3431	229	
	230	243.3161	243	229.3431	229	**
	231	243.7964	244	231.4245	231	
30	232	244.2756	244	231.4245	231	**
	233	244.7536	245	233.5163	234	
	234	245.2306	245	233.5163	234	**
	235	245.7064	246	235.6183	236	
	236	246.1811	246	235.6183	236	**
35	237	246.6547	247	237.7306	238	
	238	247.1272	247	237.7306	238	**
	239	247.5986	248	239.8532	240	
	240	248.0690	248	239.8532	240	**
	241	248.5383	249	241.9861	242	
40	242	249.0065	249	241.9861	242	**
	243	249.4737	249	241.9861	242	**
	244	249.9398	250	244.1292	244	
	245	250.4049	250	244.1292	244	**
	246	250.8690	251	246.2827	246	
45	247	251.3320	251	246.2827	246	**
	248	251.7940	252	248.4466	248	
	249	252.2550	252	248.4466	248	**
	250	252.7150	253	250.6207	251	
50	251	253.1740	253	250.6207	251	**
	252	253.6320	254	252.8052	253	
	253	254.0890	254	252.8052	253	**
	254	254.5450	255	255.0000	255	
	255	255.0000	255	255.0000	255	**

55 184 unique + 72 duplicates = 256 total

## APPENDIX B

TABLE 2

$$n = 256$$

$$m = 1024$$

$$\gamma = 2.2$$

$$S = (m - 1) = 1023$$

$$O = \text{INT}[(m - 1) \left( \frac{I}{n - 1} \right)^{\frac{1}{\gamma}} + 0.5]$$

$$I = \text{INT}[(n - 1) \left( \frac{O}{m - 1} \right)^{\gamma} + 0.5]$$

	I		O		I
	---		---		---
	0	0.0000	0	0.0000	0
20	1	82.4126	82	0.9890	1
	2	112.9342	113	2.0026	2
	3	135.7898	136	3.0102	3
	4	154.7595	155	4.0137	4
	5	171.2803	171	4.9820	5
25	6	186.0796	186	5.9944	6
	7	199.5856	200	7.0320	7
	8	212.0749	212	7.9938	8
	9	223.7383	224	9.0232	9
	10	234.7141	235	10.0268	10
30	11	245.1061	245	10.9895	11
	12	254.9944	255	12.0006	12
	13	264.4427	264	12.9522	13
	14	273.5023	274	14.0561	14
	15	282.2154	282	14.9748	15
35	16	290.6170	291	16.0464	16
	17	298.7368	299	17.0330	17
	18	306.6000	307	18.0517	18
	19	314.2284	314	18.9696	19
	20	321.6407	322	20.0492	20
40	21	328.8535	329	21.0206	21
	22	335.8813	336	22.0171	22
	23	342.7370	343	23.0389	23
	24	349.4319	349	23.9348	24
	25	355.9762	356	25.0037	25
	26	362.3794	362	25.9402	26
45	27	368.6495	369	27.0565	27
	28	374.7942	375	28.0338	28
	29	380.8203	381	29.0301	29
	30	386.7341	387	30.0454	30
	31	392.5414	393	31.0797	31
50	32	398.2473	398	31.9563	32
	33	403.8568	404	33.0258	33
	34	409.3743	409	33.9317	34
	35	414.8039	415	35.0364	35
	36	420.1496	420	35.9718	36
	37	425.4149	425	36.9207	37
55	38	430.6031	431	38.0771	38
	39	435.7174	436	39.0557	39

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	40	440.7607	441	40.0478	40
	41	445.7356	446	41.0535	41
	42	450.6448	451	42.0729	42
5	43	455.4906	455	42.8982	43
	44	460.2753	460	43.9421	44
	45	465.0011	465	44.9998	45
	46	469.6699	470	46.0712	46
	47	474.2837	474	46.9382	47
10	48	478.8443	479	48.0343	48
	49	483.3533	483	48.9212	49
	50	487.8124	488	50.0423	50
	51	492.2231	492	50.9492	51
	52	496.5869	497	52.0952	52
15	53	500.9052	501	53.0221	53
	54	505.1792	505	53.9579	54
	55	509.4103	509	54.9026	55
	56	513.5996	514	56.0961	56
	57	517.7483	518	57.0610	57
20	58	521.8575	522	58.0349	58
	59	525.9282	526	59.0177	59
	60	529.9615	530	60.0096	60
	61	533.9582	534	61.0105	61
	62	537.9194	538	62.0204	62
25	63	541.8459	542	63.0394	63
	64	545.7386	546	64.0675	64
	65	549.5982	550	65.1046	65
	66	553.4255	553	65.8884	66
	67	557.2213	557	66.9415	67
30	68	560.9864	561	68.0036	68
	69	564.7214	565	69.0749	69
	70	568.4270	568	69.8844	70
	71	572.1038	572	70.9717	71
	72	575.7524	576	72.0681	72
35	73	579.3736	579	72.8965	73
	74	582.9677	583	74.0090	74
	75	586.5355	587	75.1307	75
	76	590.0774	590	75.9781	76
	77	593.5940	594	77.1159	77
40	78	597.0858	597	77.9753	78
	79	600.5532	601	79.1294	79
	80	603.9968	604	80.0009	80
	81	607.4170	607	80.8777	81
	82	610.8142	611	82.0549	82
45	83	614.1889	614	82.9439	83
	84	617.5415	618	84.1373	84
	85	620.8724	621	85.0384	85
	86	624.1820	624	85.9449	86
	87	627.4706	627	86.8565	87
50	88	630.7387	631	88.0802	88
	89	633.9866	634	89.0041	89
	90	637.2147	637	89.9333	90
	91	640.4233	640	90.8677	91
	92	643.6126	644	92.1219	92
55	93	646.7832	647	93.0686	93
	94	649.9352	650	94.0206	94

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	95	653.0689	653	94.9779	95
	96	656.1847	656	95.9406	96
	97	659.2829	659	96.9085	97
5	98	662.3637	662	97.8817	98
	99	665.4273	665	98.8602	99
	100	668.4742	668	99.8440	100
	101	671.5045	672	101.1640	101
	102	674.5184	675	102.1603	102
10	103	677.5163	678	103.1618	103
	104	680.4983	680	103.8325	104
	105	683.4648	683	104.8430	105
	106	686.4159	686	105.8588	106
	107	689.3518	689	106.8799	107
15	108	692.2728	692	107.9064	108
	109	695.1791	695	108.9382	109
	110	698.0708	698	109.9754	110
	111	700.9483	701	111.0180	111
	112	703.8117	704	112.0659	112
20	113	706.6611	707	113.1192	113
	114	709.4969	709	113.8244	114
	115	712.3191	712	114.8867	115
	116	715.1279	715	115.9544	116
	117	717.9236	718	117.0274	117
25	118	720.7062	721	118.1058	118
	119	723.4761	723	118.8278	119
	120	726.2332	726	119.9152	120
	121	728.9779	729	121.0081	121
	122	731.7102	732	122.1063	122
30	123	734.4303	734	122.8415	123
	124	737.1384	737	123.9488	124
	125	739.8346	740	125.0615	125
	126	742.5191	743	126.1796	126
	127	745.1920	745	126.9280	127
35	128	747.8534	748	128.0552	128
	129	750.5035	751	129.1878	129
	130	753.1424	753	129.9459	130
	131	755.7702	756	131.0876	131
	132	758.3872	758	131.8518	132
40	133	760.9933	761	133.0026	133
	134	763.5888	764	134.1588	134
	135	766.1737	766	134.9327	135
	136	768.7483	769	136.0980	136
	137	771.3125	771	136.8779	137
45	138	773.8665	774	138.0524	138
	139	776.4105	776	138.8384	139
	140	778.9444	779	140.0220	140
	141	781.4686	781	140.8141	141
	142	783.9830	784	142.0068	142
50	143	786.4877	786	142.8050	143
	144	788.9829	789	144.0069	144
	145	791.4687	791	144.8112	145
	146	793.9451	794	146.0222	146
	147	796.4123	796	146.8326	147
55	148	798.8704	799	148.0528	148
	149	801.3194	801	148.8694	149

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	150	803.7595	804	150.0988	150
	151	806.1907	806	150.9214	151
	152	808.6132	809	152.1600	152
5	153	811.0270	811	152.9888	153
	154	813.4322	813	153.8201	154
	155	815.8288	816	155.0716	155
	156	818.2171	818	155.9090	156
	157	820.5970	821	157.1697	157
10	158	822.9687	823	158.0132	158
	159	825.3322	825	158.8592	159
	160	827.6876	828	160.1329	160
	161	830.0350	830	160.9851	161
	162	832.3745	832	161.8397	162
15	163	834.7060	835	163.1263	163
	164	837.0298	837	163.9871	164
	165	839.3459	839	164.8504	165
	166	841.6544	842	166.1500	166
	167	843.9552	844	167.0195	167
20	168	846.2486	846	167.8915	168
	169	848.5345	849	169.2040	169
	170	850.8131	851	170.0822	170
	171	853.0843	853	170.9628	171
	172	855.3484	855	171.8459	172
25	173	857.6052	858	173.1752	173
	174	859.8550	860	174.0646	174
	175	862.0977	862	174.9564	175
	176	864.3334	864	175.8507	176
	177	866.5622	867	177.1968	177
30	178	868.7842	869	178.0973	178
	179	870.9994	871	179.0003	179
	180	873.2078	873	179.9058	180
	181	875.4095	875	180.8138	181
	182	877.6046	878	182.1804	182
35	183	879.7932	880	183.0947	183
	184	881.9752	882	184.0114	184
	185	884.1508	884	184.9306	185
	186	886.3200	886	185.8523	186
	187	888.4828	888	186.7765	187
40	188	890.6393	891	188.1676	188
	189	892.7896	893	189.0980	189
	190	894.9336	895	190.0310	190
	191	897.0715	897	190.9665	191
	192	899.2034	899	191.9045	192
45	193	901.3292	901	192.8450	193
	194	903.4489	903	193.7880	194
	195	905.5628	906	195.2072	195
	196	907.6707	908	196.1565	196
	197	909.7728	910	197.1083	197
50	198	911.8690	912	198.0626	198
	199	913.9595	914	199.0194	199
	200	916.0443	916	199.9787	200
	201	918.1234	918	200.9406	201
	202	920.1968	920	201.9050	202
55	203	922.2647	922	202.8719	203
	204	924.3270	924	203.8413	204



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	205	926.3838	926	204.8132	205
	206	928.4351	928	205.7877	206
5	207	930.4810	930	206.7646	207
	208	932.5216	933	208.2348	208
	209	934.5568	935	209.2181	209
	210	936.5866	937	210.2040	210
	211	938.6113	939	211.1923	211
10	212	940.6306	941	212.1832	212
	213	942.6449	943	213.1766	213
	214	944.6539	945	214.1725	214
	215	946.6578	947	215.1710	215
	216	948.6567	949	216.1720	216
15	217	950.6505	951	217.1755	217
	218	952.6393	953	218.1816	218
	219	954.6232	955	219.1902	219
	220	956.6021	957	220.2014	220
	221	958.5761	959	221.2151	221
20	222	960.5452	961	222.2313	222
	223	962.5095	963	223.2501	223
	224	964.4690	964	223.7604	224
	225	966.4238	966	224.7830	225
	226	968.3738	968	225.8081	226
25	227	970.3191	970	226.8358	227
	228	972.2597	972	227.8660	228
	229	974.1957	974	228.8988	229
	230	976.1271	976	229.9341	230
	231	978.0540	978	230.9720	231
30	232	979.9762	980	232.0124	232
	233	981.8940	982	233.0553	233
	234	983.8073	984	234.1009	234
	235	985.7161	986	235.1489	235
	236	987.6205	988	236.1995	236
35	237	989.5205	990	237.2527	237
	238	991.4161	991	237.7803	238
	239	993.3074	993	238.8373	239
	240	995.1944	995	239.8969	240
	241	997.0771	997	240.9590	241
40	242	998.9556	999	242.0237	242
	243	1000.8298	1001	243.0909	243
	244	1002.6998	1003	244.1607	244
	245	1004.5656	1005	245.2331	245
	246	1006.4273	1006	245.7703	246
45	247	1008.2849	1008	246.8465	247
	248	1010.1384	1010	247.9253	248
	249	1011.9877	1012	249.0066	249
	250	1013.8331	1014	250.0906	250
	251	1015.6744	1016	251.1770	251
50	252	1017.5118	1018	252.2661	252
	253	1019.3451	1019	252.8116	253
	254	1021.1745	1021	253.9045	254
	255	1023.0000	1023	255.0000	255

55 256 unique + 0 duplicates = 256 total

## Claims

1. An image display system comprising:  
a source (10) of image pixel data wherein each pixel has an M-bit value within a non-linear range of values;  
5 characterized by  
first means (16), coupled to an output of said source, for converting each of said M-bit pixel values to an N-bit value within a linear range of values;  
10 storage means (18), having an input coupled to an output of said first converting means, for storing the N-bit pixel values; and  
second means (20), coupled to an output of said storage means (18), for converting N-bit pixel values output by said storage means to P-bit pixel values within a non-linear range of values prior to the application of said  
15 converted P-bit pixel data to a display means, wherein M preferably is greater than N and wherein P preferably is equal to or greater than N.
2. Image display system as set forth in claim 1, wherein said first converting means (16) operates in accordance with a gamma correction function and wherein said second converting means (20) operates in accordance with an  
20 inverse gamma correction function.
3. Image display system as set forth in claim 1 or 2, wherein said first converting means (16) includes a first memory means having address inputs coupled to said M-bit pixel values, said first memory means having a plurality of entries each of which stores a gamma corrected pixel value.  
25
4. Image display system according to any one of the preceding claims, wherein said second converting means (20) includes a second memory means having address inputs coupled to said N-bit pixel values, said second memory means having a plurality of entries each of which stores an inverse gamma corrected pixel value.
- 30 5. Image display system according to any one of the preceding claims, wherein said first memory means and said second memory means are each coupled to means for storing said corrected pixel values therein.
6. Image display system according to any one of the preceding claims, wherein said second memory means stores a plurality of sets of inverse gamma corrected pixel values, and wherein said storage means further stores, for  
35 each of the N-bit pixel values, a value that specifies a particular one of said plurality of sets of inverse gamma corrected pixel values for use in converting an associated one of said N-bit pixel values.
7. Image display system according to any one of the preceding claims, wherein P and N are related to an expression  $E = [s(e)^{1/Y}/s]^Y$ , where E is a video signal voltage and where y is a power function exponent, both of which are  
40 associated with the display means, and where the coefficient S satisfies the following relations:

$$O = \text{INT}[(P-1)(I/N-1)^{1/y} + 0.5]$$

45 and

$$I = \text{INT}[(N-1)(O/P-1)^y + 0.5],$$

50 where N  $\equiv$  a number of linear input (I) levels, P  $\equiv$  a number of gamma corrected output (O) levels, (I/N-1) and (O/P-1) are normalized input and output values, respectively, S = P-1, and INT is a truncating integer function.

8. Image display system according to any one of the preceding claims, wherein said source means (10) further comprises an analog-to-digital conversion means having an input for receiving the inverse gamma corrected signal from said camera and an output for expressing the inverse gamma corrected signal with M-bits.  
55
9. Image display system according to any one of the preceding claims and further including a digital-to-analog conversion means having a P-bit input coupled to an output of said second converting means.

10. A method of operating an image display system, comprising the steps of:  
generating image pixel data wherein each pixel has an M-bit value within a non-linear range of values;  
characterized by the further steps of:

5 converting each of the M-bit pixel values to an N-bit value within a linear range of values;

storing the N-bit pixel values;

10 converting N-bit pixel values output by said storage means to P-bit pixel values within a non-linear range of values; and

said method preferably further comprising a step of applying the converted P-bit pixel data to a display means;

15 wherein M preferably is greater than N and wherein P preferably is equal to or greater than N.

11. Method as set forth in claim 10, wherein said first step of converting operates in accordance with a gamma correction function and wherein the second step of converting operates in accordance with an inverse gamma correction function and said second step of converting preferably converts the N-bit pixel values in accordance with one of a plurality of sets of inverse gamma corrected pixel values.

- 20 12. Method as set forth in claims 10 or 11, wherein the second step of converting includes a step of specifying, for each N-bit pixel value, a particular one of the plurality of sets of inverse gamma corrected pixel values.

- 25 13. Method according to any one of claims 10 to 12, wherein M and N are related to an expression  $E = [s(e)^{1/Y}/s]^Y$ , where E is a video signal voltage and where y is a power function exponent both of which are associated with the display means, and where the coefficient S satisfies the following relations:

$$O = \text{INT}[(P-1)(I/N-1)^{1/Y} + 0.5]$$

30 and

$$I = \text{INT}[(N-1)(O/P-1)^Y + 0.5],$$

35 where N ≡ a number of linear input (I) levels, P = a number of gamma corrected output (O) levels, (I/N-1) and (O/P-1) are normalized input and output values, respectively, S = P-1, and INT is a truncating integer function.

- 40 14. Method according to any one of claims 10 to 13 and further including a step of digital-to-analog converting the P-bit pixel values.

- 45 15. An image display apparatus comprising:  
a source (10) of image pixel data wherein each pixel is expressed with M-bits within a non-linear range of values;  
characterized by

means (16), coupled to an output of said source, for gamma correcting each of said M-bit pixel values to an N-bit value within a linear range of values;

50 frame buffer means (18), having an input coupled to an output of said first converting means, for storing the gamma converted N-bit pixel values, said frame buffer means being preferably coupled to a host means operable for storing N-bit image pixel data therein;

means (20), coupled to an output of said frame buffer means, for inverse gamma correcting N-bit pixel values output by said frame buffer means to P-bit pixel values; and

55 means, coupled to an output of said inverse gamma correcting means, for converting the P-bit pixel data to an analog voltage for driving a CRT-display means, wherein M preferably is greater than N and wherein P preferably is equal to or greater than N.

16. Image display apparatus as set forth in claim 15, wherein said first look-up table means and said second look-up table means are each coupled to a host means operable for storing gamma correction values and inverse gamma correction values, respectively, therein.

17. Image display apparatus according to claim 15 or 16, wherein said second look-up table means stores a plurality of sets of inverse gamma corrected pixel values, and wherein said frame buffer means (18) further stores, for each of the N-bit pixel values, a value expressed with W-bits that specifies a particular one of said plurality of sets of inverse gamma corrected pixel values for use in converting an associated one of said N-bit pixel values.

18. Image display apparatus according to any one of claims 15 to 17, wherein said frame buffer means (18) is comprised of  $xN+W$ -bit memory planes, where x is a number of color signal inputs to said CRT-display means.

## Patentansprüche

1. Ein Bildanzeigesystem, das eine Quelle (10) von Bilddaten enthält, wobei jedes Pixel einen M-Bit-Wert innerhalb eines nichtlinearen Wertebereiches besitzt; gekennzeichnet durch

erste Mittel (16), die mit einem Ausgang der Quelle verbunden sind, zur Konvertierung aller M-Bit-Pixelwerte in einen N-Bit-Pixelwert innerhalb eines linearen Wertebereiches;

Speichermittel (18), die einen Eingang besitzen, der mit einem Ausgang der ersten Konvertierungsmittel verbunden ist, zur Speicherung der N-Bit-Pixelwerte ; und

Speichermittel (20), die mit einem Ausgang der Speichermittel (18) verbunden sind, zur Konvertierung von N-Bit-Pixelwerten, die durch die Speichermittel ausgegeben werden, in P-Bit-Pixelwerte in einem nichtlinearen Wertebereich vor dem Anlegen der konvertierten P-Bit-Pixeldaten an ein Anzeigemittel, wobei M vorzugsweise größer als N ist und P vorzugsweise größer oder gleich N ist.

2. Anzeigesystem nach in Anspruch 1, wobei das erste Konvertierungsmittel (16) entsprechend einer Gammakorrekturfunktion arbeitet und das zweite Konvertierungsmittel (20) entsprechend einer inversen Gammakorrekturfunktion arbeitet.

3. Anzeigesystem nach Anspruch 1 oder 2, wobei das erste Konvertierungsmittel (16) ein erstes Speichermittel enthält, dessen Adreßeingänge mit den M-Bit-Pixelwerten verbunden sind, wobei das erste Speichermittel eine Vielzahl von Eintragungen besitzt, von denen jede einen gammakorrigierten Pixelwert speichert.

4. Bildanzeigesystem nach einem der vorhergehenden Ansprüche, wobei das zweite Konvertierungsmittel (20) ein zweites Speichermittel enthält, das Adreßeingänge besitzt, die mit den N-Bit-Pixelwerten verbunden sind, wobei das zweite Speichermittel eine Vielzahl von Eintragungen besitzt, von denen jede einen inversen gammakorrigierten Pixelwert speichert.

5. Bildanzeigesystem nach einem der vorhergehenden Ansprüche, wobei das erste Speichermittel und das zweite Speichermittel jeweils mit Mitteln zur Speicherung der korrigierten Pixelwerte verbunden sind.

6. Bildanzeigesystem nach einem der vorhergehenden Ansprüche, wobei das zweite Speichermittel eine Vielzahl von Mengen inverser gammakorrigierter Pixelwerte speichert und wobei das Speichermittel weiterhin für jeden der N-Bit-Pixelwerte einen Wert speichert, der eine spezielle Menge aus der Vielzahl von Mengen von inversen gammakorrigierten Pixelwerten zur Verwendung bei der Konvertierung eines zugeordneten N-Bit-Pixelwertes spezifiziert.

7. Bildanzeigesystem nach einem der vorhergehenden Ansprüche, wobei P und N in Beziehung zu einem Ausdruck  $E = [S(e)^{1/Y}/S]^Y$  stehen, wobei E eine Videosignalspannung und Y der Exponent einer Exponentialfunktion ist, die beide den Anzeigemitteln zugeordnet sind und wobei der Koeffizient S die folgenden Beziehungen erfüllt:

$$O = \text{INT}[(P-1)(I/N-1)^{1/y} + 0,5]$$

und

$$I = \text{INT}[(N-1)(O/P-1)^y + 0,5],$$

wobei N eine Anzahl von linearen Eingabe- (I) Pegeln ist, P eine Anzahl von gammakorrigierten Ausgabe- (O) Pegeln ist, (I/N-1) und (O/P-1) normierte Ein- bzw. Ausgabewerte sind, S gleich P-1 ist und INT eine Funktion ist, die ganze Zahlen durch Abschneiden erzeugt.

8. Bildanzeigesystem nach einem der vorhergehenden Ansprüche, wobei das Quellenmittel (10) weiterhin ein Analog-Digital-Konvertierungsmittel enthält, das einen Eingang für den Empfang des inversen gammakorrigierten Signals von der Kamera und einen Ausgang zur Darstellung des inversen gammakorrigierten Signals durch N Bits besitzt.

9. Bildanzeigesystem nach einem der vorhergehenden Ansprüche, das weiterhin ein Digital-Analog-Konvertierungsmittel besitzt, das einen P-Bit-Eingang besitzt, der mit einem Ausgang des zweiten Konvertierungsmittels verbunden ist.

10. Verfahren zum Betrieb eines Bildanzeigesystems, das die folgenden Schritte umfaßt:  
Erzeugung von Bildpixelwerten, wobei jedes Pixel einen M-Bit-Wert in einem nichtlinearen Wertebereich besitzt; gekennzeichnet durch die folgenden weiteren Schritte:

Konvertierung jedes M-Bit-Pixelwertes in einen N-Bit-Wert in einem linearen Wertebereich;

Speicherung der N-Bit-Pixelwerte;

Konvertierung der N-Bit-Pixelwerte, die von dem Speichermittel ausgegeben wird, in P-Bit-Pixelwerte in einem nichtlinearen Wertebereich; und

wobei die Methode vorzugsweise weiterhin einen Schritt enthält, die konvertierten P-Bit-Pixeldaten an ein Anzeigemittel anzulegen;

wobei M vorzugsweise größer als N ist und wobei P vorzugsweise größer oder gleich N ist.

11. Verfahren nach Anspruch 10, wobei der erste Schritt der Konvertierung entsprechend einer Gammakorrekturfunktion arbeitet und der zweite Schritt der Konvertierung entsprechend einer inversen Gammakorrekturfunktion arbeitet und der zweite Konvertierungsschritt vorzugsweise die N-Bit-Pixelwerte entsprechend einer Menge aus einer Vielzahl von Mengen von inversen gammakorrigierten Pixelwerten konvertiert.

12. Verfahren nach Anspruch 10 oder 11, wobei der zweite Schritt der Konvertierung einen Schritt enthält, für jeden N-Bit-Pixelwert eine spezielle Menge aus einer Vielzahl von Mengen von inversen gammakorrigierten Pixelwerten zu spezifizieren.

13. Verfahren nach einem der Ansprüche 10 bis 12, wobei M und N in Beziehung zu einem Ausdruck  $E = [S(e)^{1/y}/S]^y$  stehen, wobei E eine Videosignalspannung und y der Exponent einer Exponentialfunktion ist, die beide den Anzeigemitteln zugeordnet sind und wobei der Koeffizient S die folgenden Beziehungen erfüllt:

$$O = \text{INT}[(P-1)(I/N-1)^{1/y} + 0,5]$$

und

$$I = \text{INT}[(N-1)(O/P-1)^y + 0,5],$$

wobei N eine Anzahl von linearen Eingabe- (I) Pegeln ist, P eine Anzahl von gammakorrigierten Ausgabe- (O) Pegeln ist,  $(I/N-1)$  und  $(O/P-1)$  normierte Ein- bzw. Ausgabewerte sind,  $S = P-1$  ist und INT eine Funktion ist, die ganze Zahlen durch Abschneiden erzeugt.

14. Verfahren nach einem der Ansprüche 10 bis 13, das weiterhin einen Schritt der Digital-Analog-Konvertierung der P-Bit-Pixelwerte enthält.

15. Bildanzeigevorrichtung, die enthält eine Quelle (10) von Bildpixeldaten, wobei jedes Pixel durch M Bits in einem nichtlinearen Wertebereich ausgedrückt wird; gekennzeichnet durch

Mittel (16), die mit einem Ausgang der Quelle verbunden sind, zur Gammakorrektur aller M-Bit-Pixelwerte in einen N-Bit-Wert innerhalb eines linearen Wertebereiches;

Rasterpuffermittel (18), die einen Eingang besitzen, der mit einem Ausgang der ersten Konvertierungsmittel verbunden ist, zur Speicherung der gammakonvertierten N-Bit-Pixelwerte, wobei das Rasterpuffermittel vorzugsweise mit einem Hostrechtermittel verbunden ist, das geeignet ist, die N-Bit-Bildpixeldaten dort zu speichern;

Mittel (20), die mit einem Ausgang des Rasterpuffermittels (18) verbunden sind, zur inversen Gammakorrektur der N-Bit-Pixelwerte, die durch das Rasterpuffermittel ausgegeben werden, in P-Bit-Pixelwerte; und

Mittel, die mit einem Ausgang der inversen Gammakorrekturmittel verbunden sind, zur Konvertierung der P-Bit-Pixeldaten in eine analoge Spannung zur Steuerung eines CRT-Anzeigemittels, wobei M vorzugsweise größer als N und P vorzugsweise größer oder gleich N ist.

16. Bildanzeigevorrichtung nach Anspruch 15 dargestellt, wobei das erste Nachschlagtabellenmittel und das zweite Nachschlagtabellenmittel jeweils mit einem Hostrechtermittel verbunden sind, das zur Speicherung der Gammakorrekturwerte und der inversen Gammakorrekturwerte geeignet ist.

17. Bildanzeigevorrichtung entsprechend Anspruch 15 oder 16, wobei das zweite Nachschlagtabellenmittel eine Vielzahl von Mengen von inversen gammakorrigierten Pixelwerten speichert und das Rasterpuffermittel (18) weiterhin für jeden der N-Bit-Pixelwerte einen mit W Bit ausgedrückten Wert speichert, der eine spezielle Menge aus der Vielzahl von Mengen inverser gammakorrigierter Pixelwerte spezifiziert, zur Verwendung bei der Konvertierung eines zugeordneten N-Bit-Pixelwertes.

18. Bildanzeigevorrichtung nach einem der Ansprüche 15 bis 17, wobei das Rasterpuffermittel (18) aus  $xN+W$ -Bit-Speicherebenen besteht, wobei x eine Anzahl von Farbsignaleingängen des CRT-Anzeigemittels ist.

## Revendications

1. Système d'affichage d'image comprenant:

une source (10) de données de pixel d'image dans laquelle chaque pixel a une valeur de M bits dans une plage non linéaire de valeurs; caractérisé par

un premier moyen (16), couplé à une sortie de ladite source, pour convertir chacune desdites valeurs de pixel à M bits, en une valeur à N bits dans une plage linéaire de valeurs;

un moyen de stockage (18), comportant une entrée couplée à une sortie dudit premier moyen de conversion, pour le stockage des valeurs de pixel à N bits; et

un second moyen (20), couplé à une sortie dudit moyen de stockage (18), pour convertir les valeurs de pixel à N bits délivrées par ledit moyen de stockage en valeurs de pixel à P bits dans une plage non linéaire de valeurs avant l'application desdites données de pixel à P bits converties à un moyen d'affichage, dans lequel M est de préférence supérieur à N et dans lequel P est de préférence égal ou supérieur à N.

2. Système d'affichage d'image selon la revendication 1, dans lequel ledit premier moyen de conversion (16) fonc-

tionne conformément à une fonction de correction du gamma et dans lequel ledit second moyen de conversion (20) fonctionne conformément à une fonction inverse de correction du gamma.

3. Système d'affichage d'image selon la revendication 1 ou 2, dans lequel ledit premier moyen de conversion (16) comporte un premier moyen formant mémoire ayant des entrées d'adresse couplées auxdites valeurs de pixel à M bits, ledit moyen formant mémoire ayant une pluralité d'entrées chacune d'elles stockant une valeur de pixel corrigée en gamma.
4. Système d'affichage d'image selon l'une quelconque des revendications précédentes, dans lequel ledit second moyen de conversion (20) comporte un second moyen formant mémoire ayant des entrées d'adresse couplées auxdites valeurs de pixel à N bits, ledit second moyen formant mémoire ayant une pluralité d'entrées chacune d'elles stockant une valeur de pixel corrigée en gamma inverse.
5. Système d'affichage d'image selon l'une quelconque des revendications précédentes, dans lequel ledit premier moyen formant mémoire et ledit second moyen formant mémoire sont couplés chacun à un moyen pour stocker lesdites valeurs de pixel corrigées.
6. Système d'affichage d'image selon l'une quelconque des revendications précédentes, dans lequel ledit second moyen formant mémoire stocke une pluralité de séries de valeurs de pixel corrigées en gamma inverses, et dans lequel ledit moyen de stockage stocke en outre, pour chacune des valeurs de pixel à N bits, une valeur qui spécifie une série particulière parmi ladite pluralité de séries de valeurs de pixel corrigées en gamma inverses destinées à être utilisées dans la conversion d'une valeur associée parmi lesdites valeurs de pixel à N bits.
7. Système d'affichage d'image selon l'une quelconque des revendications précédentes, dans lequel P et N sont relatifs à une expression  $E = [s(e)^{1/Y} / S]^Y$ , où E est une tension de signal vidéo et où y est un exposant de fonction de puissance, les deux étant associés au moyen d'affichage, et où le coefficient S satisfait aux relations suivantes:

$$O = \text{INT} [(P - 1) (I/N - 1)^{1/Y} + 0,5]$$

et

$$I = \text{INT} [(N - 1) (O/P - 1)^Y + 0,5],$$

où N = le nombre de niveaux d'entrée linéaires (I), P = le nombre de niveaux de sorties corrigées en gamma (O), (I/ N-1) et (O/ P - 1) sont des valeurs normalisées d'entrée et de sortie, respectivement, S = P - 1, et INT est une fonction entière de troncature.

8. Système d'affichage d'image selon l'une quelconque des revendications précédentes, dans lequel ledit moyen (10) formant source comprend en outre un moyen de conversion analogique-numérique ayant une entrée pour recevoir le signal corrigé en gamma inverse en provenance de ladite caméra et une sortie destinée à exprimer le signal corrigé en gamma inverse avec M bits.
9. Système d'affichage d'image selon l'une quelconque des revendications précédentes, et comportant en outre un moyen de conversion numérique-analogique ayant une entrée à P bits couplée à une sortie dudit second moyen de conversion.
10. Procédé de fonctionnement d'un système d'affichage d'image comprenant les étapes suivantes: génération de données de pixel d'image dans lesquelles chaque pixel a une valeur à M bits dans une plage non linéaire de valeurs; caractérisé par les étapes supplémentaires suivantes:

conversion de chacune des valeurs de pixel à M bits en une valeur à N bits dans une plage linéaire de valeurs; stockage des valeurs de pixel à N bits; conversion des valeurs de pixel à N bits délivrées par ledit moyen de stockage en valeurs de pixel à P bits dans une plage non linéaire de valeurs; et ledit procédé comprenant en outre et de préférence une étape d'application desdites données de pixel à P bits converties à un moyen d'affichage;

dans lequel M est de préférence supérieur à N et dans lequel P est de préférence égal ou supérieur à N.

11. Procédé selon la revendication 10, dans lequel ladite première étape de conversion fonctionne conformément à une fonction de correction du gamma et dans lequel la seconde étape de conversion fonctionne conformément à une fonction de correction du gamma inverse et ladite seconde étape de conversion convertit de préférence les valeurs de pixel à N bits en fonction de l'une d'une pluralité de séries de valeurs de pixel corrigées en gamma inverses.

12. Procédé selon les revendications 10 ou 11, dans lequel la seconde étape de conversion comporte une étape de spécification, pour chaque valeur de pixel à N bits, d'une série particulière parmi la pluralité de séries de valeurs de pixel corrigées en gamma inverses.

13. Procédé selon l'une quelconque des revendications 10 à 12, dans lequel M et N sont relatifs à une expression  $E = [S(e)^{1/Y} / S]^Y$ , où E est une tension de signal vidéo et où y est un exposant de fonction de puissance, les deux étant associés au moyen d'affichage, et où le coefficient S satisfait aux relations suivantes:

$$O = \text{INT} [(P - 1) (I/N - 1)^{1/Y} + 0,5]$$

et

$$I = \text{INT} [(N - 1) (O/P - 1)^Y + 0,5],$$

où N = le nombre de niveaux d'entrée linéaires (I), P = le nombre de niveaux de sorties corrigées en gamma (O), (I/ N-1) et (O/ P - 1) sont des valeurs normalisées d'entrée et de sortie, respectivement, S = P - 1, et INT est une fonction entière de troncature.

14. Procédé selon l'une quelconque des revendications 10 à 13 et comportant en outre une étape de conversion numérique-analogique convertissant les valeurs de pixel à P bits.

15. Appareil d'affichage d'image comprenant:

une source (10) de données de pixel d'image dans laquelle chaque pixel est exprimé par M bits dans une plage non linéaire de valeurs;  
caractérisé par

un moyen (16), couplé à une sortie de ladite source, pour la correction du gamma de chacune des valeurs de pixel à M bits en une valeur à N bits dans une plage linéaire de valeurs;

un moyen (18) formant tampon de trame, ayant une entrée couplée à une sortie dudit premier moyen de conversion, pour le stockage des valeurs de pixel à N bits converties en gamma; ledit moyen formant tampon de trame étant de préférence couplé à un moyen formant hôte pouvant fonctionner pour le stockage des données de pixel à N bits;

un moyen (20), couplé à une sortie dudit moyen formant tampon de trame, pour une correction inverse du gamma des valeurs de pixel à N bits délivrées par ledit moyen formant tampon de trame en valeurs de pixel à P bits; et

un moyen, couplé à une sortie dudit moyen de correction inverse du gamma, pour convertir les données de pixel à P bits en une tension analogique pour la commande d'un moyen d'affichage à CRT, dans lequel M est de préférence supérieur à N et dans lequel P est de préférence égal ou supérieur à N.

16. Appareil d'affichage d'image selon la revendication 15, dans lequel ledit premier moyen formant table de consultation et ledit second moyen formant table de consultation sont couplés chacun à un moyen formant hôte pouvant fonctionner pour stocker des valeurs de correction du gamma et des valeurs de correction inverse du gamma, respectivement.

17. Appareil d'affichage d'image selon la revendication 15 ou 16, dans lequel ledit second moyen formant table de consultation stocke une pluralité de séries de valeurs de pixel corrigées en gamma inverses, et dans lequel ledit moyen (18) formant tampon de trame stocke en outre, pour chacune des valeurs de pixel à N bits, une valeur exprimée par W bits qui spécifie une série particulière de ladite pluralité de séries de valeurs de pixel corrigées



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en gamma inverses destinées à être utilisées dans la conversion d'une valeur associée desdites valeurs de pixel à N bits.

- 5    **18.** Appareil d'affichage d'image selon l'une quelconque des revendications 15 à 17, dans lequel ledit moyen (18) formant tampon de trame est constitué de plans de mémoire de  $xN + W$  - bits, où x est le nombre d'entrées du signal de couleur dans ledit moyen d'affichage à CRT.

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FIG. 1A  
(PRIOR ART)

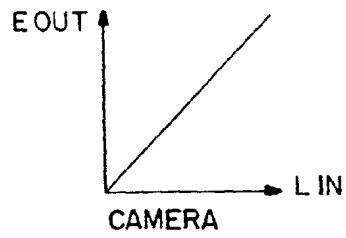


FIG. 1C  
(PRIOR ART)

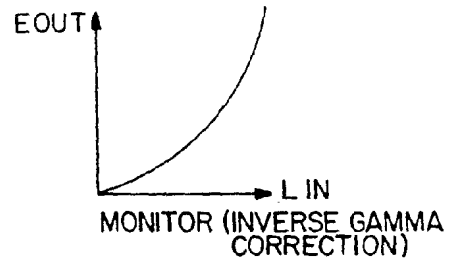


FIG. 1B  
(PRIOR ART)

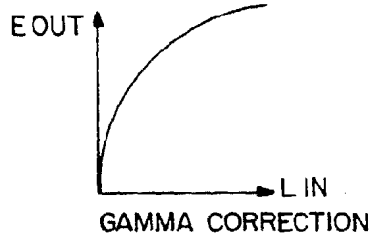


FIG. 1D  
(PRIOR ART)

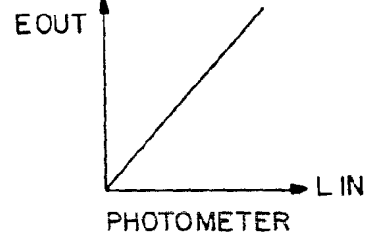


FIG. 2

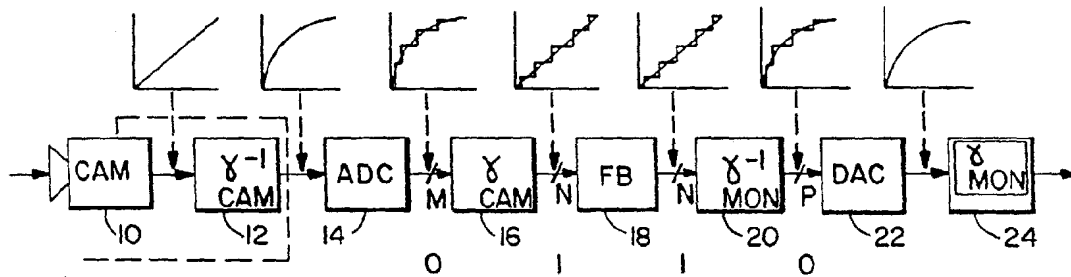
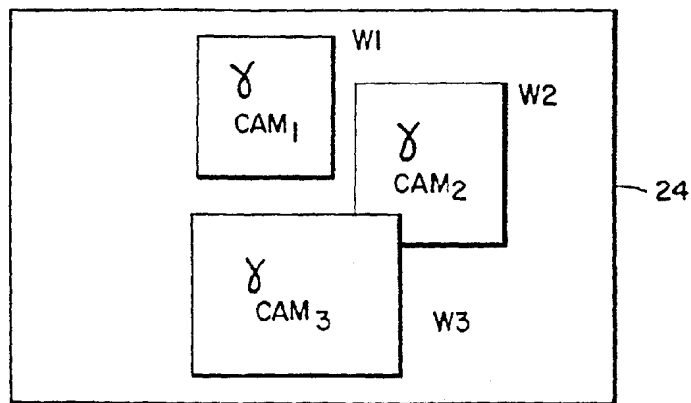


FIG. 3



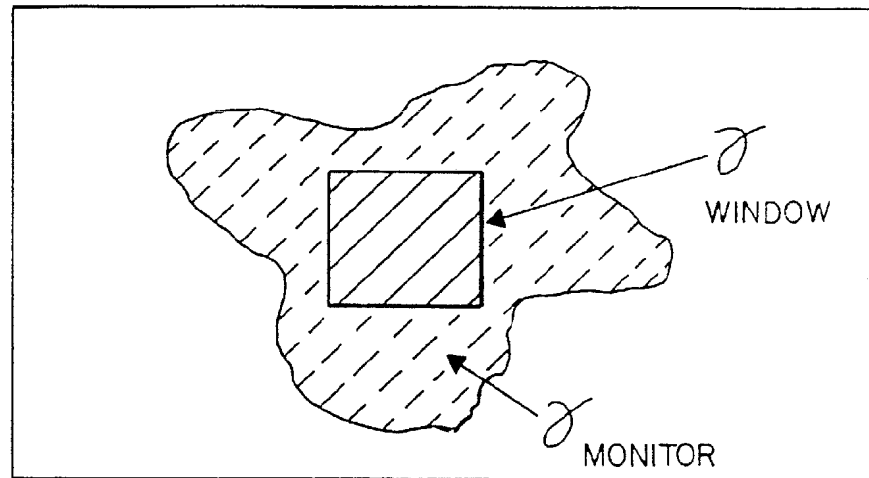
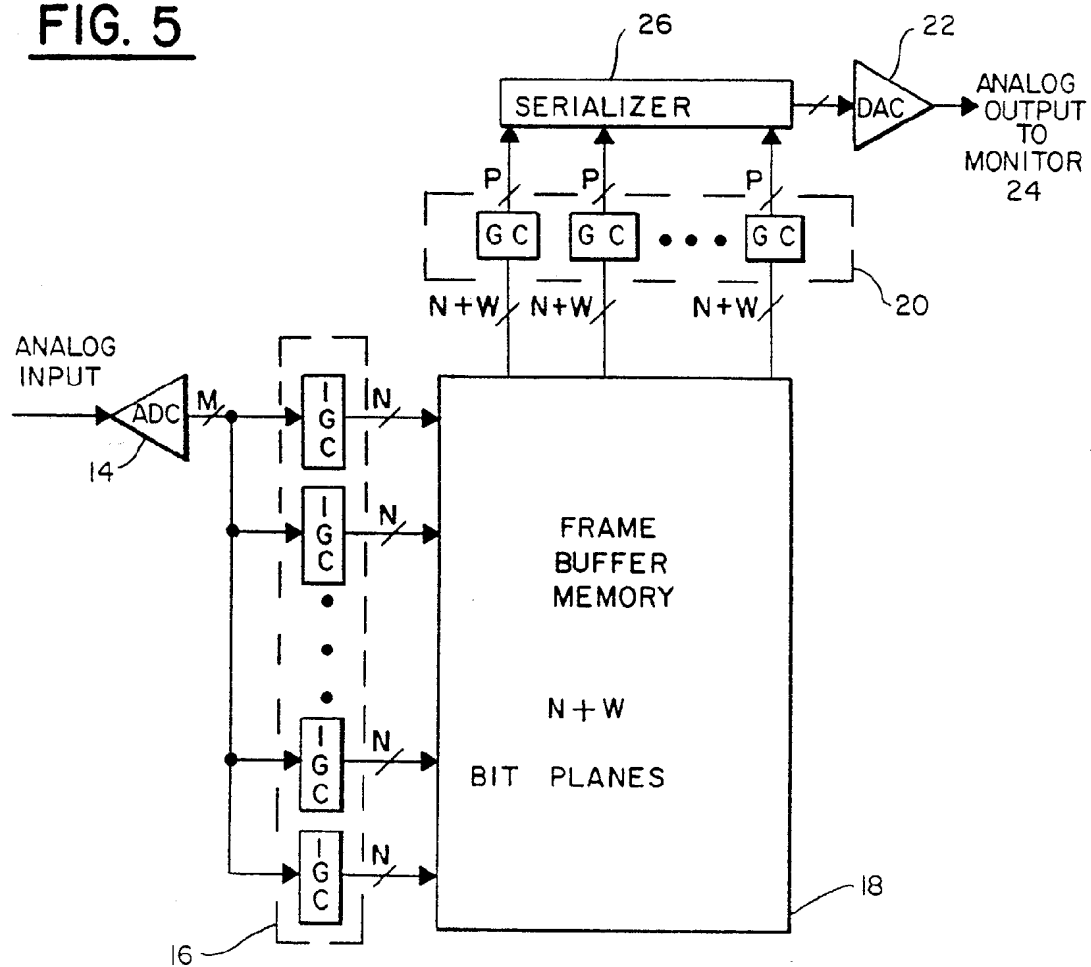
**FIG. 4****FIG. 5**

FIG. 6

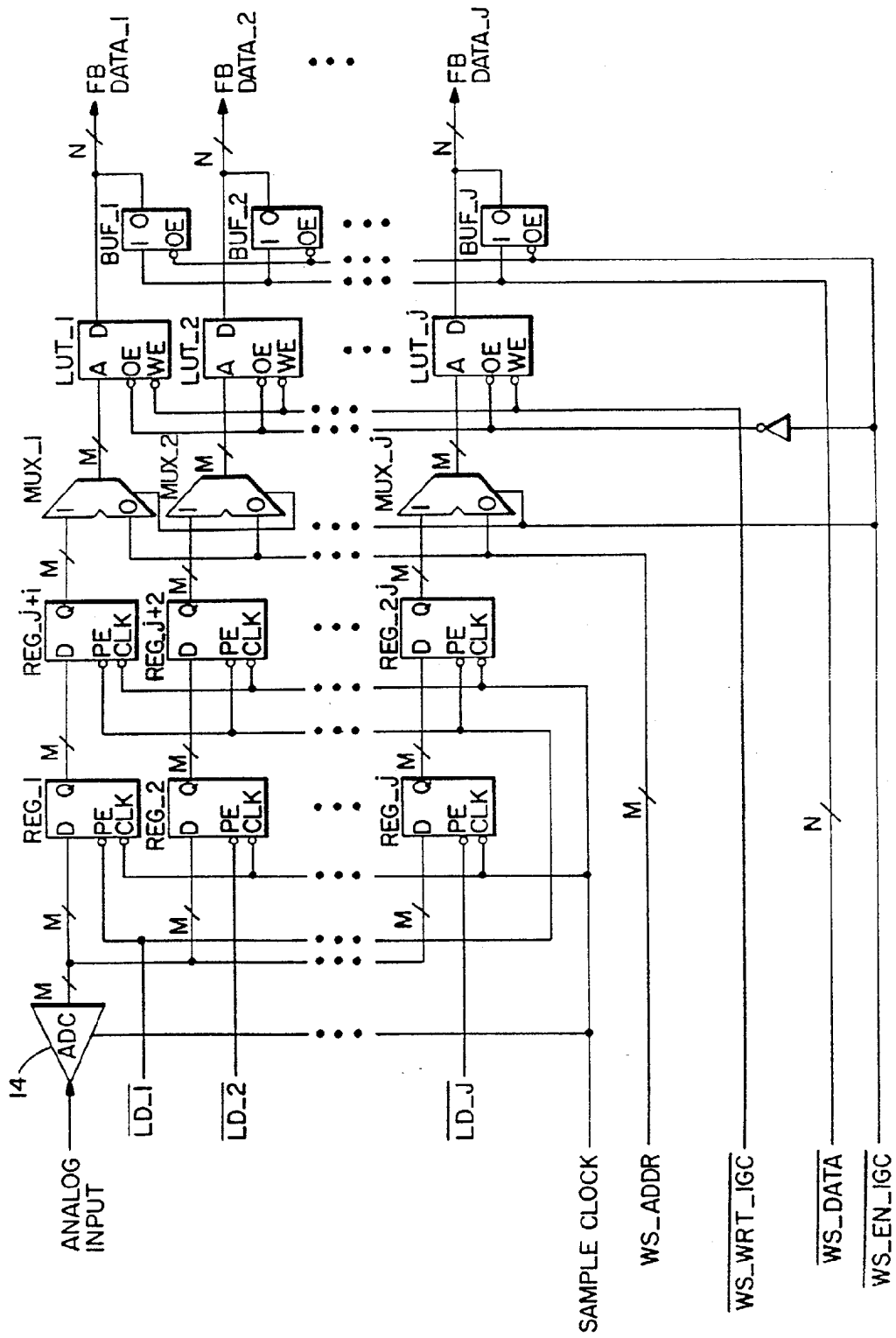


FIG. 7

